AD 693775

CLOTHING & ORGANIC MATERIALS DIVISION

Engineering Report No. 305

CORRELATION OF LABORATORY INSTRUMENTS IN MEASURING THE ABRASION RESISTANCE OF MAN-MADE FIBER FABRICS AND BLENDS

By

Louis I. Weiner
and
Clarence J. Pope

Project No. 7X79-01-002

January 1963

14

CORRELATION OF LABORATORY INSTRUMENTS IN MEASURING THE ABRASION RESISTANCE OF MAN-MADE FIBER FABRICS AND BLENDS

Introduction

Abrasion resistance is a function of machine factors such as speed, nature of the abradant, tension and pressure; fabric factors such as work-to-rupture of the component fibers and geometry of the yarns and fabric; and the interaction between the machine and the fabric, which includes such things as friction, moisture and temperature (1, 2). Recently, a significant amount of attention has been given to the abrasion characteristics of man-made fiber fabrics and blends as a result of the important functional properties which such fabrics offer in areas such as absorption of thermal energy, flame resistance, chemical resistance and "comfort" in use (3). The first systematic study of the abrasion characteristics of man-made fibers was probably that of Hamburger (4) who showed that a factor governing the abrasion resistance of different fiber species was work-to-rupture, and who was able to obtain an excellent relationship between "durability coefficients" and "energy coefficients" for a number of different materials.

At present, a study is underway in our laboratory of the abrasion resistance of 15 prototype fabrics representing single fiber constructions and blends of 12 different fibers. The purpose of evaluating this group of fabrics is to obtain, ~~if possible,~~ a pattern of performance which may be relatable to inherent properties such as work-to-rupture, melting point, and friction. This particular report presents an interesting by-product of this study, which demonstrates the relatedness of some laboratory instruments for evaluating wear and the consistency with theories of wear, which have been established primarily for metals, but have been found applicable to viscoelastic materials also.

Experimental Procedure

The fabrics selected for this study included most of the fiber classes defined by the Federal Trade Commission such as: nylon, polyester, acrylic, modacrylic, nytril, viscose and triacetate. In addition, they represented both filament and spun yarn constructions in blends and 100% single fiber composition. Several weave types and fabric weights were used. The fabric samples were all tested with the back adjacent to the abradant. This procedure was followed in order to make the results consistent with those obtained on the standard 8.6 oz. carded cotton sateen, which is normally worn with the back of the fabric to the outside of the garment. In the case of 10 of the fabrics, which were of a plain weave, the reversal from face to back would make no difference since these constructions are identical on both sides. In the case of the other 5 fabrics, three of which were sateens and two twills, the reversal would make a difference in level of abrasion obtained. However, since all military sateens are worn with the back of the fabric to the outside, this procedure is logical and normal for the three sateens. For the two twills then, recognition should be given to this reversal in interpreting the abrasion results obtained. The fabrics were evaluated in the warp direction only, on the Stoll, BFT, and Sand Abraders. On the Taber abrader the action is multidirectional, so that both yarn systems were subjected to the abrasive action.

The mechanical action of the four abrasion machines has been described previously (5, 6, &7). A sketch summarizing the essential differences in mechanical action of the four machines is given in Figure 1.

The notations "adhesive" and "abrasive" wear in Figure 1 refer to the two theories for the wear of metals developed by Archard and Rabinowicz, which are applicable in some respects to textile fabrics. Adhesive wear is a type of wear action which results from interactions at the surface of the material being abraded and the abradant. The forces involved are molecular in nature--leading to the formation of molecular welds which are sheared by relative motion of the surface, producing wear particles. Since this is a surface phenomenon, adhesive wear is markedly reduced by the presence of boundary lubricants. Abrasive wear, on the other hand, involves an actual penetration through the surface of the material being abraded by an abradant particle. Relative motion then results in the gouging or plouging out of material. Since the surface of the material is penetrated by the abradant, this type of wear is relatively insensitive to the presence of lubricants. Studies made on the wear course at Fort Lee and some practical wear trials indicate that the type of field wear of most concern to the Army is "abrasive". On the other hand, there are special areas, such as in the cuffs of trousers, where wear is probably predominantly adhesive.

Previous work done in our laboratories demonstrated that the Stoll and BFT abraders are of the adhesive wear producing type, and results obtained on this instrument will be considerably influenced by the presence or absence of lubricants on the fabric being evaluated. As much as a 7-fold increase in abrasion life on these machines can result from the application of a relatively small amount of a lubricating type finish to a fabric. The Taber and Sand Abraders, on the other hand, are of the abrasive type. In both instances, abradant particles penetrate through the surface of the fabric being abraded and gouge out fibrous substance by a snagging or cutting action. In both of these instruments, the presence of lubricant in the fabric has little effect on the end result obtained.

The end-point of tests on the Stoll and BFT abraders is the number of cycles to rupture. This is an objective end-point and requires no interpretation on the part of the operator. The end-point of the tests on the Taber and Sand abraders is the number of cycles to produce a certain predetermined level of apparent damage as determined by visual examination. This is a subjective end-point which requires considerable interpretation on the part of the operator. Separate studies (8) are being conducted to investigate systems for making this end-point more objective. Accordingly, the values reported for the Taber and Sand abraders have relative significance only, since the absolute magnitude of the cycles may vary depending upon the operator and the level of damage desired for the particular sequence of samples being run. In this particular study, the evaluation of the end-point was made by one operator over a very short time span and every effort was made to be consistent from sample-to-sample.

Results

Complete data for the abrasion tests are given in Table I. Particular attention should be given to the variety of fiber compositions, the range in weights and the different weave types employed. The scale values for the different test instruments is worth noting. The Stoll results ranged from 190 to 15,570 with an average of 4570 cycles. The BFT from 120 to 16,640 with an average of 3560. Taber from 110 to 3900--average of 1040. Sand from 940 to 8000--average of 3750. The high values for the BFT and Stoll are characteristic of fabrics with a lubricating type of surface finish. Elimination of this finish by chloroform extraction would probably reduce the high Stoll and BFT values to a much lower range. Also noteworthy is the fact that the BFT values average less than the Stoll. This is a result of the more rapid oscillation of the flex blade of the BFT. The BFT is thus more economical from the standpoint of number of samples which can be run per unit of time. Likewise, the Taber is more efficient than the Sand abrader from this standpoint. On the other hand, with longer times to failure, it is possible to obtain more precision in results with a larger spread among sample averages. Logarithmic plots of the data are presented in Figures 2 to 7, inclusive. The closest agreement is obtained in the plots of Taber vs Sand (Figure 2) and Stoll vs BFT (Figure 3). This is a consequence of the fact that in each of these plots the same type of abrasion is being evaluated. On the other hand, the plots of Sand vs BFT (Figure 4) and Taber vs Stoll (Figure 5) do not show as good agreement, which would be an expected result since the instruments in each of these groups represent different types of abrasive action. Stoll vs Sand (Figure 6) and Taber vs BFT (Figure 7) also do not agree as well. An estimate of the spread in data was obtained by summing the squares of the distances of the individual points from the estimated regression line. While this is not statistically precise, it serves as a rough measure of variability from the straight lines. The sums of the squares for the various correlations are presented in Table II.

TABLE I

PHYSICAL PROPERTIES AND ABRASION RESISTANCE OF VARIOUS SYNTHETIC AND BLENDED FABRICS

Fabric VEE No.	Fiber Content %	Fabric Code	Fabric Weight Oz/Yd^2	Fabric Weave	EFT Abrader Cycles to Rupture Warp	Stoll Abrader Cycles to Rupture Warp	Taber Abrader Cycles	Sand Abrader Cycles
711B	Modacrylic-100	M	6.8	Plain	770	770	400	2260
727	Cotton-100	C	8.5	Sateen	1160	2420	380	2740
771	Cotton-70 Nylon-30	C/N	8.5	Sateen	4180	7130	1670	4990
798	Polyester D-50 Cotton-50	Pd/C	6.7	2/1 LH-Twill	5540	7970	860	4300
851E	Polyester D-100 (Filament)	Pd	7.7	Plain	9690	11750	3890	8000
868A	Modacrylic-50 Nylon-50	M/N	8.0	Plain	430	1880	1380	7160
869	Nytril-D-100	Nd	7.7	Plain	160	190	700	1160
870A	Cotton-50 Nytril-D-50	C/Nd	7.4	Plain	240	230	400	2620
872A	Cotton-50 Acrylic Z-50	C/Az	7.6	Plain	250	340	310	1120
874A	Acrylic Z-100	Az	8.1	Plain	210	260	220	1320
924	Polyester D (Fil) (Warp) Acrylic (Filling)	Pd/Ao	8.0	Sateen	5040	6160	810	2800
999	Triacetate-40 Polyester F-30 Viscose-30	T/Pf/V	8.7	2/1 RH Twill	2920	2600	2110	4480
1005B	Cotton Warp	C/6	8.5	Plain	6010	10820	1570	6300
1011B	Fiber 6-100	6	7.9	Plain	16640	15570	1330	6000
K	Polyester X-100	Px	4.1	Plain	120	280	110	940

TABLE II

Sums of Squares of Linear Deviations from Regression Lines

	BFT	STOLL	TABER	SAND
BFT	---	880	3360	1970
STOLL	880	---	2860	1590
TABER	3360	2860	---	280
SAND	1970	1590	280	---

For instruments that produce the same types of wear actions, the sums of squares are relatively low, e.g. 880 (BFT vs Stoll) and 280 (Sand vs Taber). For instruments that produce different types of wear actions, the sums of squares are relatively high, e.g. 1970 (Sand vs BFT) and 3360 (Taber vs BFT). While these data cannot be accepted as absolute proof of the similarity in mechanisms of the machines involved, they do show a strong association between the theoretical expectations and the experimental evidence. The fact that these relationships were determined on a spectrum of samples ranging as widely as these did in fiber composition, weave type, and weight adds some strength to the conclusions that are drawn.

Conclusions

1. Abrasion machines which produce similar types of wear actions tend to correlate with each other for a wide range of textile fabric types.

2. The Taber and Sand abraders which produce a type of wear action which may be described as "abrasive" correlate closely within rather narrow tolerance limits.

3. The BFT and Stoll abraders which produce a type of wear action which may be described as "adhesive" correlate closely within rather narrow tolerance limits.

4. Instruments which produce different types of wear actions do not correlate as well.

Recommendations

1. It is recommended that the BFT abrader be used in lieu of the Stoll where it is desired to obtain an indication of "adhesive" type wear. Evaluations made on the BFT should be done with both extracted

and unextracted samples to segregate the influence of the presence of lubricant type finishes.

2. It is recommended that a more detailed study be made of both the Sand and Taber abraders, and possibly of other abraders such as the Wyzenbeek and the Rotary Impact, to determine whether an objective end-point can be worked out for any of these instruments in the interest of having a more precise tool for evaluating "abrasive" wear, which is of prime importance for combat and utility clothing.

References

1. Ball, H. J. - "Problems Which Abrasion and Wear Testing Present", Textile Research Journal

2. Backer, S. - "Wear Resistance", Textile Series Report No. 61, OQMG, R&D, (September 1949)

3. Weiner, L. I. - "Some Aspects of the Performance of Man-Made Fibers in Military Clothing Fabrics", Textile Engineering Report No. 300, May 1962

4. Hamburger, W. J. - "Mechanics of Abrasion of Textile Materials", Textile Research Journal, 15, 169, (1945)

5. Federal Specification CCC-T-191b - Textile Test Methods - Nos. 5300 and 5306 - (Description of Stoll and Taber Abraders)

6. "Abrasion Resistance of Spun Rayon Blend Fabrics With Crease-Resistant Finishes Determined by BFT Mark III Tester", Second Revised Edition, Diamond Industry Supply Association, Ltd., 35 Greenville Street, Holborn, London, E. C. I., England (August 1956)

7. Weiner, L. I., - "A Survey of 18-Ounce Blended Serge Fabrics: Wear Resistance, QM Research and Engineering Command, Textile Series Report No. 123, November 1962, (Description of Sand Abrader)

8. Weiner, L. I., - "Analysis of the Rate of Abrasion of Textile Fabrics Using Beta Absorption Techniques", MER No. 8226, 1 November 1962.

MECHANISM OF ACTION OF ABRADERS

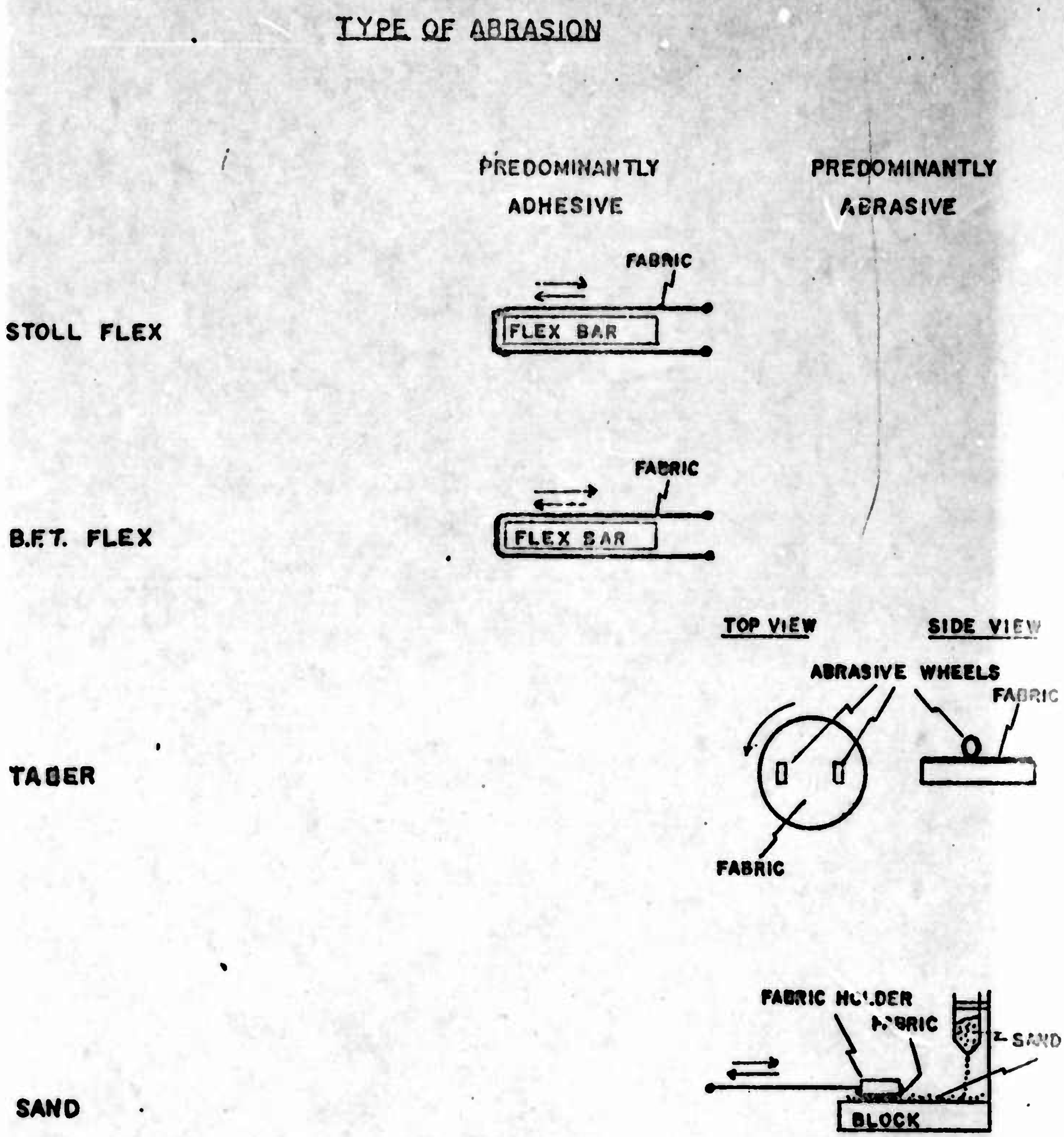

Figure 1

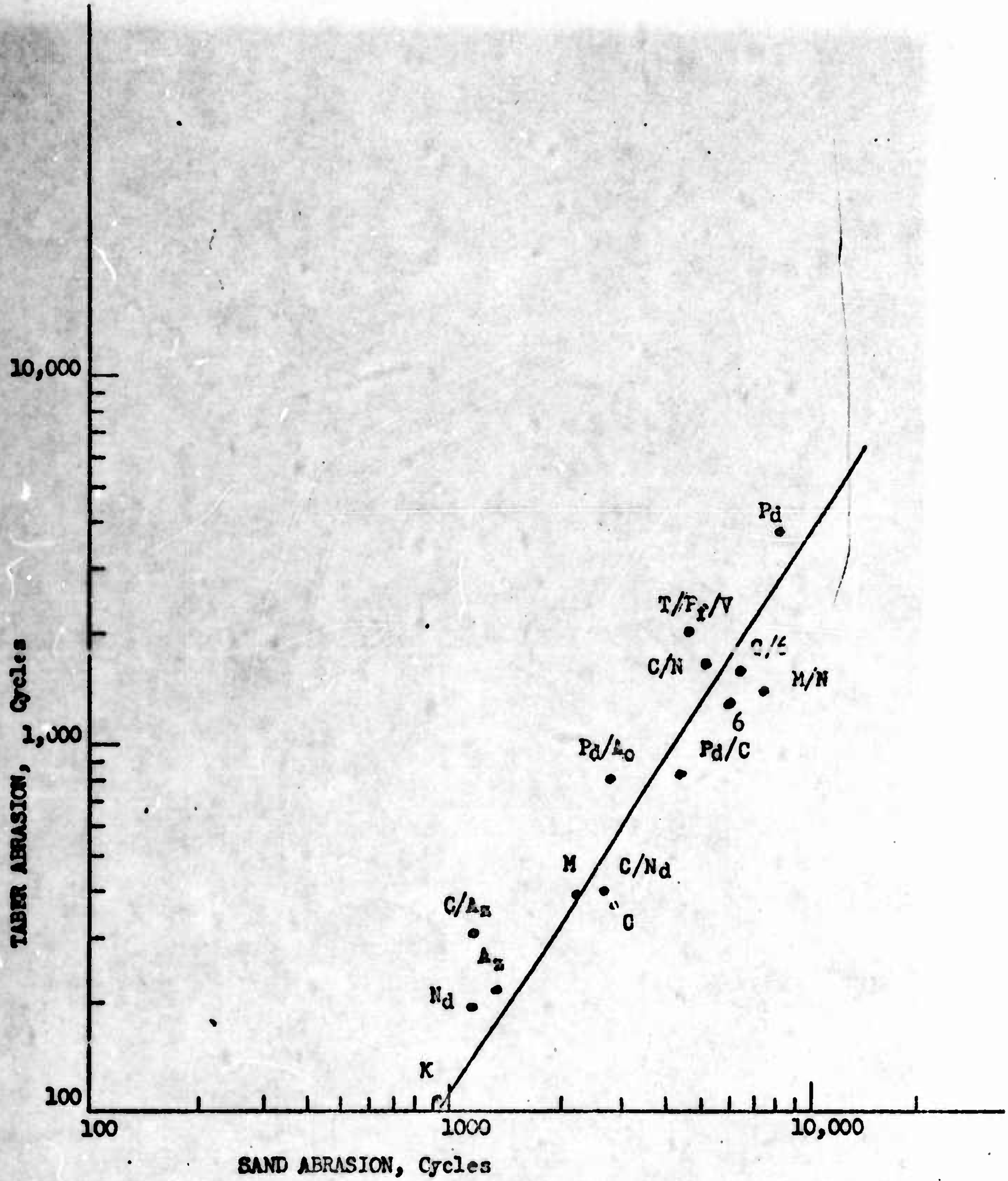

Figure 2. Comparison of Taber and Sand Abrasion

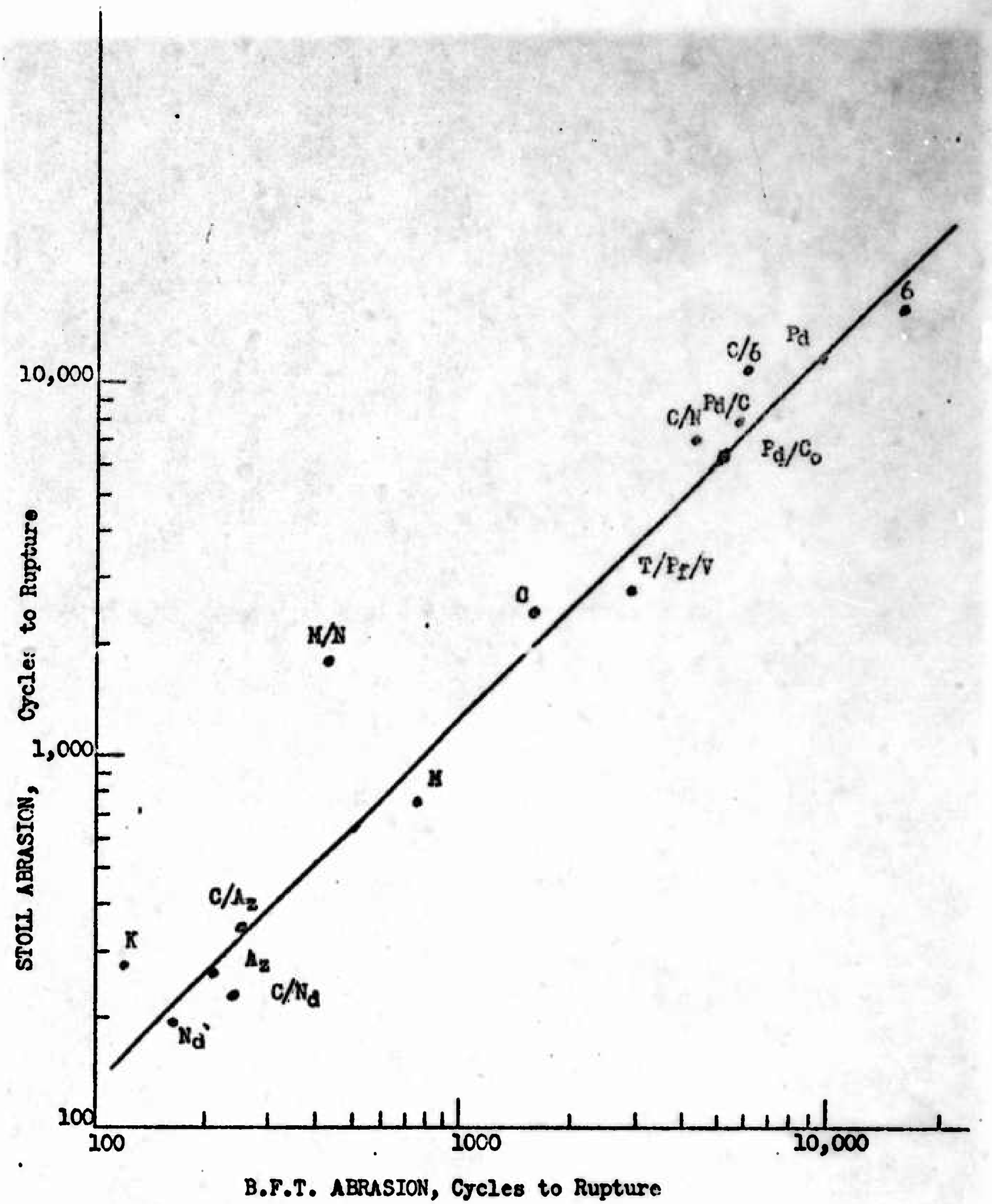

Figure 3. Comparison of Stoll and BFT Abrasion

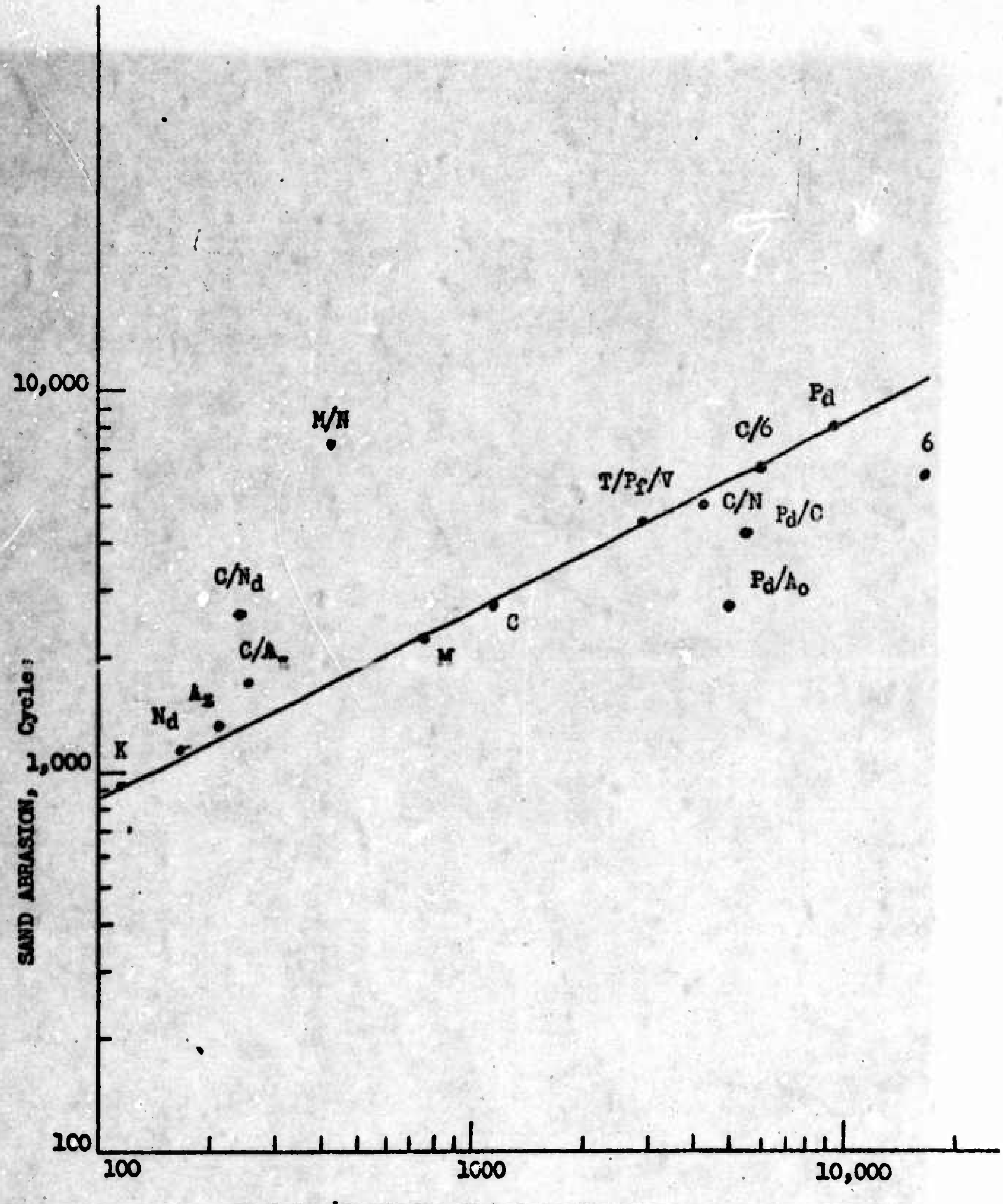

Figure 4. Comparison of Sand and BFT Abrasion

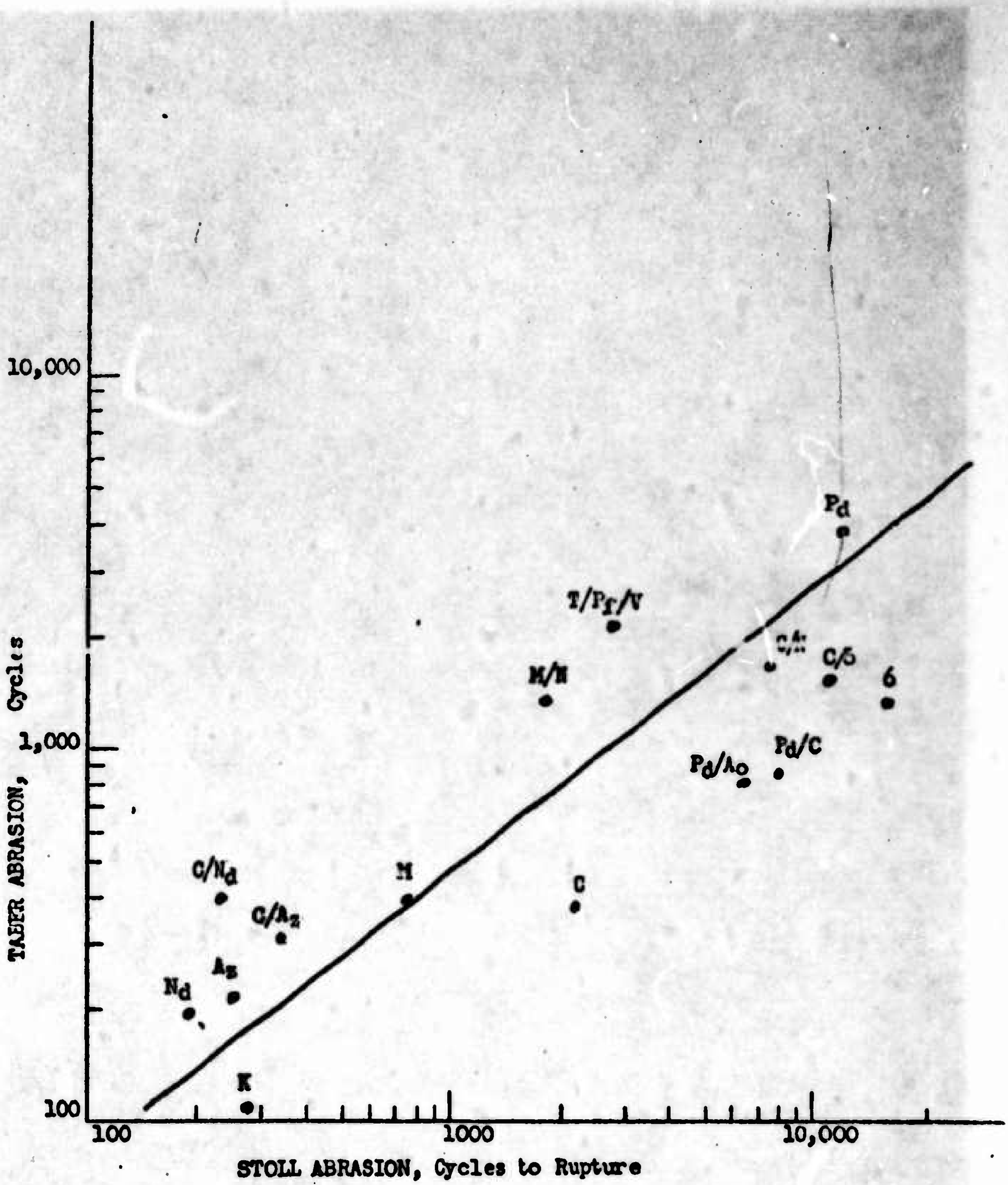

Figure 5. Comparison of Taber and Stoll Abrasion

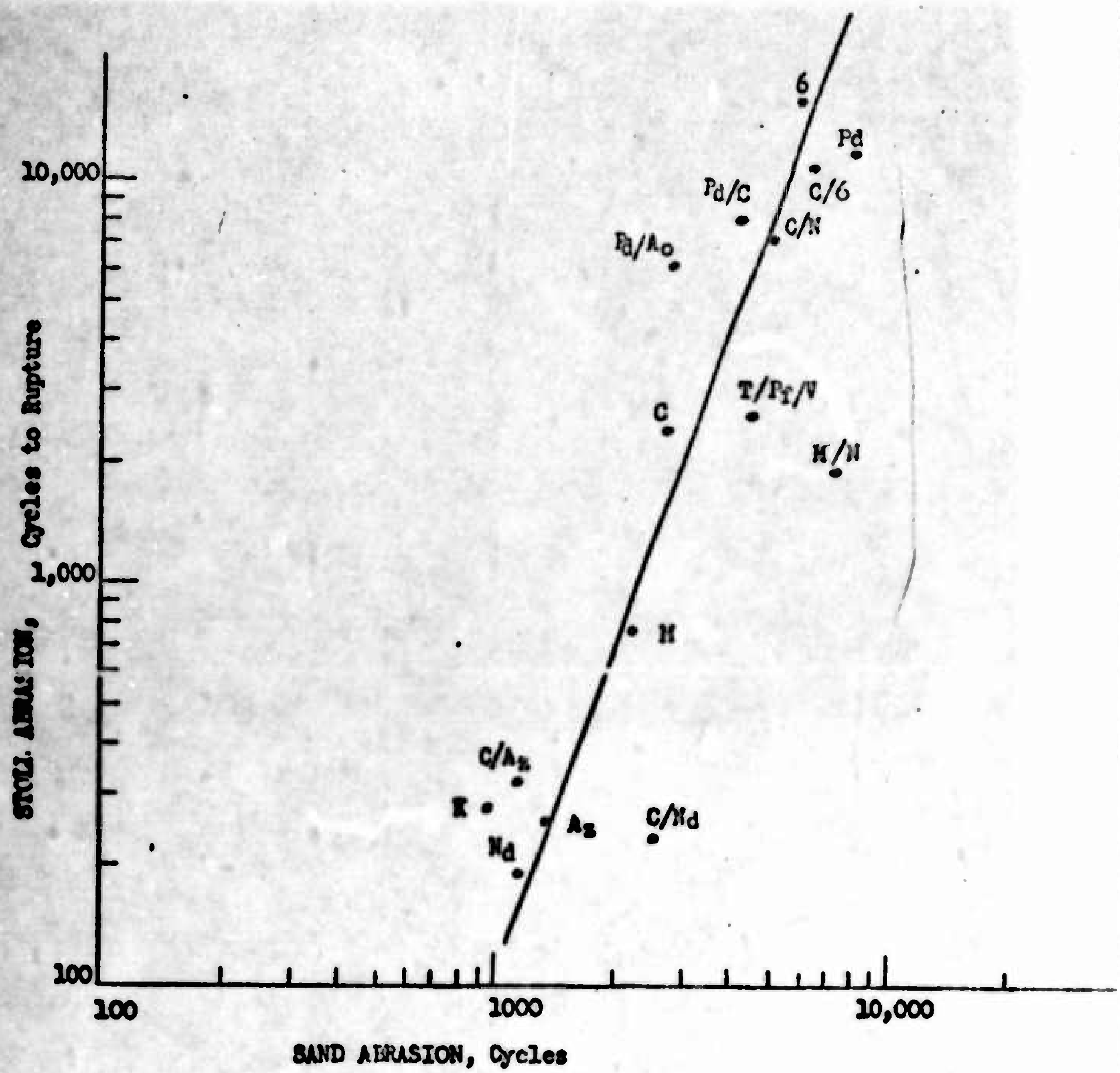

Figure 6. Comparison of Stoll and Sand Abrasion

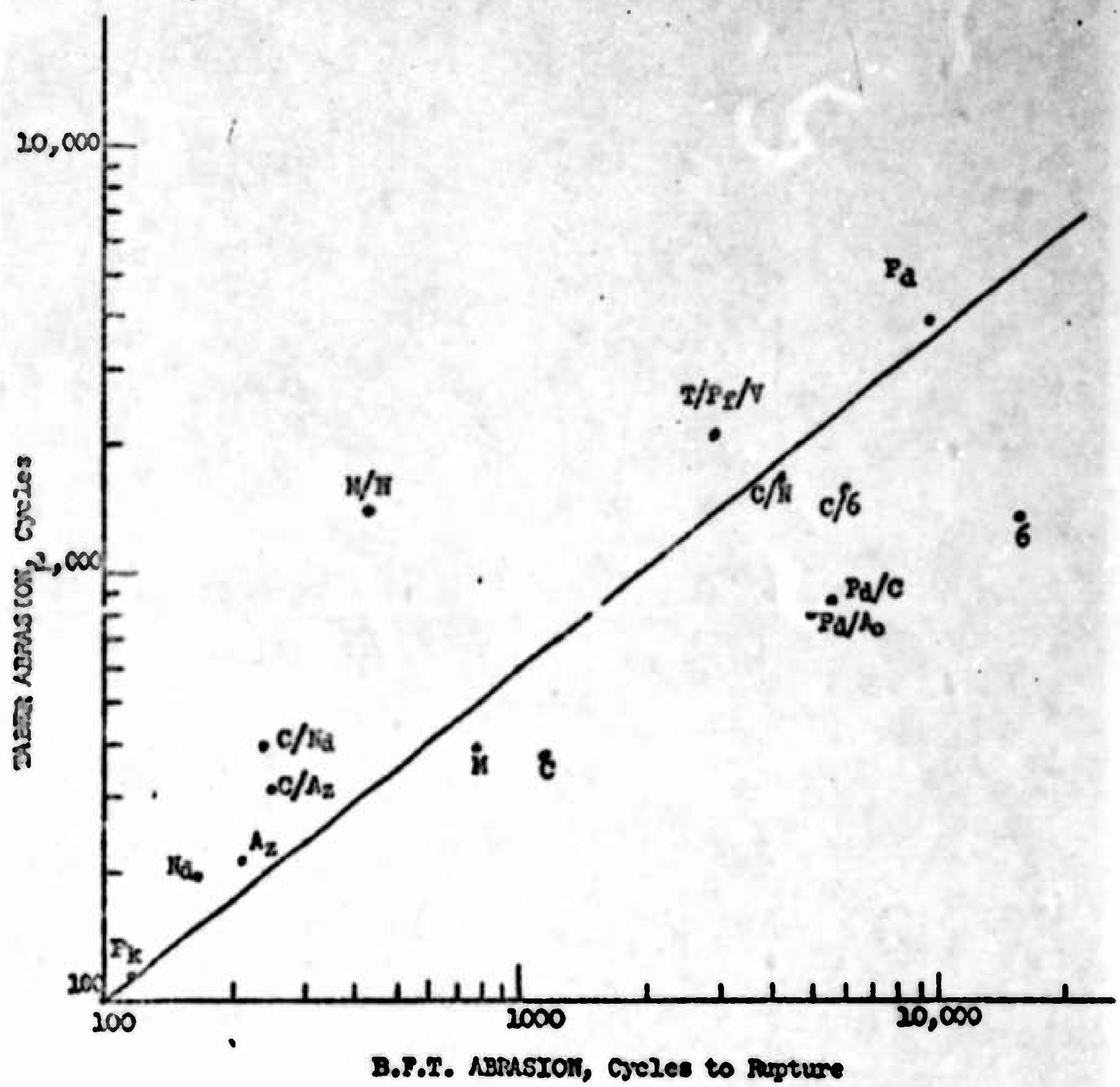

Figure 7. Comparison of Taber and BFT Abrasion